PART 4

LM2-TOXIC

Appendix 4.5.5. Primary Production for the LM2-Toxic

Amy Anstead
Welso Federal Services, LLC
Large Lakes Research Station
9311 Groh Road
Grosse Ile, Michigan 48138

The LM2-Toxic hindcast model (1940-1995) relies on external measurements or calculations to provide the internally produced (primary production) carbon loads. There have been very few studies published that estimated lake-wide primary productivity for Lake Michigan (Fee, 1973). It is, therefore, difficult to put together a primary productivity history from 1940-1995 as required for the model hindcast. However, historical total phosphorus loads and concentration values were available, and a relationship between total phosphorus and primary productivity was used to estimate primary productivity. Lake Michigan total phosphorus loads were estimated from 1974-1991 by the International Joint Commission (IJC) (Great Lakes Water Quality Board, 1989; Pauer *et al.,* 2006), and for 1994-1995 as part of Lake Michigan Mass Balance Project (LMMBP) (described in Part 2). Prior to 1974, there were only a few reports published that documented measured total phosphorus loads (Patalas, 1972; Lee 1974). However, total phosphorus loads from 1800-1970 were estimated using a model that incorporated phosphorus sources and sinks for the Great Lakes (Chapra, 1977). There were reliable lake-wide total phosphorus concentration data from 1976 to present and measurements dating back to the 1950s (Risley and Fuller, 1965; Rockwell *et al.,*

1980). In most cases the data prior to 1976 were location specific, and it was difficult to extrapolate the results to obtain a representative lake-wide total phosphorus concentration.

Modeled loads from 1800-1850 (Chapra, 1977) were higher than measured total phosphorus loads from 1994-95 (Figure 4.5.5.1). It was curious that measured total phosphorus loads in recent times of higher anthropogenic phosphorus input (1994-1995) were lower than modeled total phosphorus loads during the pre-Western civilization period (1800-1850). There seemed to be a disconnect between the measured loads of recent times and the loads modeled for the 1800s. The model simulation was recreated and extended until 2000. As expected, the model overpredicted total phosphorus loads when compared with the measured data (Figure 4.5.5.1). Improvements were made to the model parameters which resulted in a better fit to the measured data from 1974-1995 (Figure 4.5.5.1). Modifications to the model included decreasing phosphorus export coefficients for land use, decreasing per capita detergent phosphorus export and decreasing atmospheric phosphorus loads. All modifications made fell within reported literature values for the Great Lakes system (Reckhow and Simpson, 1980; Rast and Lee, 1983; U.S. Environmental Protection Agency, 1976). The model also simulated annual average surface water total phosphorus concentration for Lake Michigan by simply dividing modeled total phosphorus load by lake volume. Modeled total phosphorus concentration compared well to measured total phosphorus concentration values for Lake Michigan (Rockwell *et al.*, 1980; Risley and Fuller,1965; Beeton and Moffett, 1964;
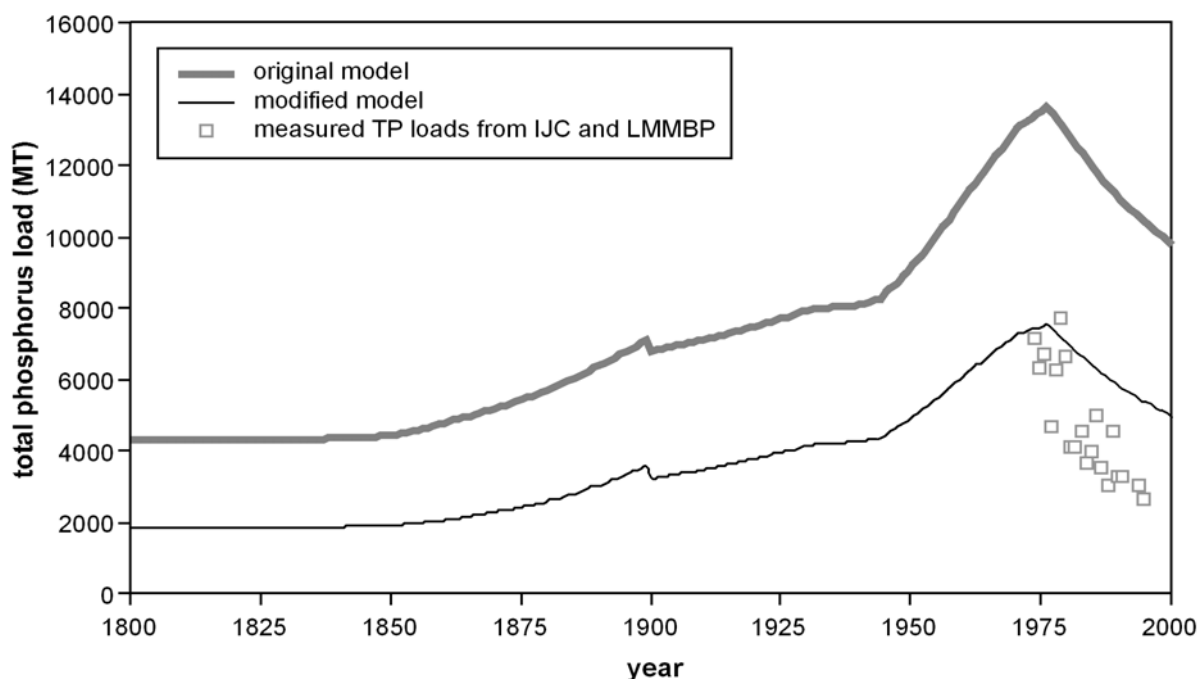
Figure 4.5.5.1. Model data versus measured total phosphorus loads.

Holland,1969; Rousar and Beeton, 1973) (Figure 4.5.5.2). The adjusted model output provided a complete annual average total phosphorus concentration history from which primary productivity was calculated.

Vollenweider *et al*. (1974) established a relationship between total phosphorus load and primary productivity but it was limited by few values from a time when phosphorus loads and primary productivity were at their highest in Lake Michigan's history. The relationship was not as strong for years with lower total phosphorus loads. We established a total phosphorus-primary productivity relationship (Figure 4.5.5.3) from the output of a 1976-1995 hindcast of the eutrophication model, LM3-Eutro. This relationship was used to calculate lake-wide annual primary productivity from 1940-1995 Total phosphorus concentration history. Final annual primary production (as organic carbon) was provided as a spreadsheet for incorporation into LM2-Toxic.

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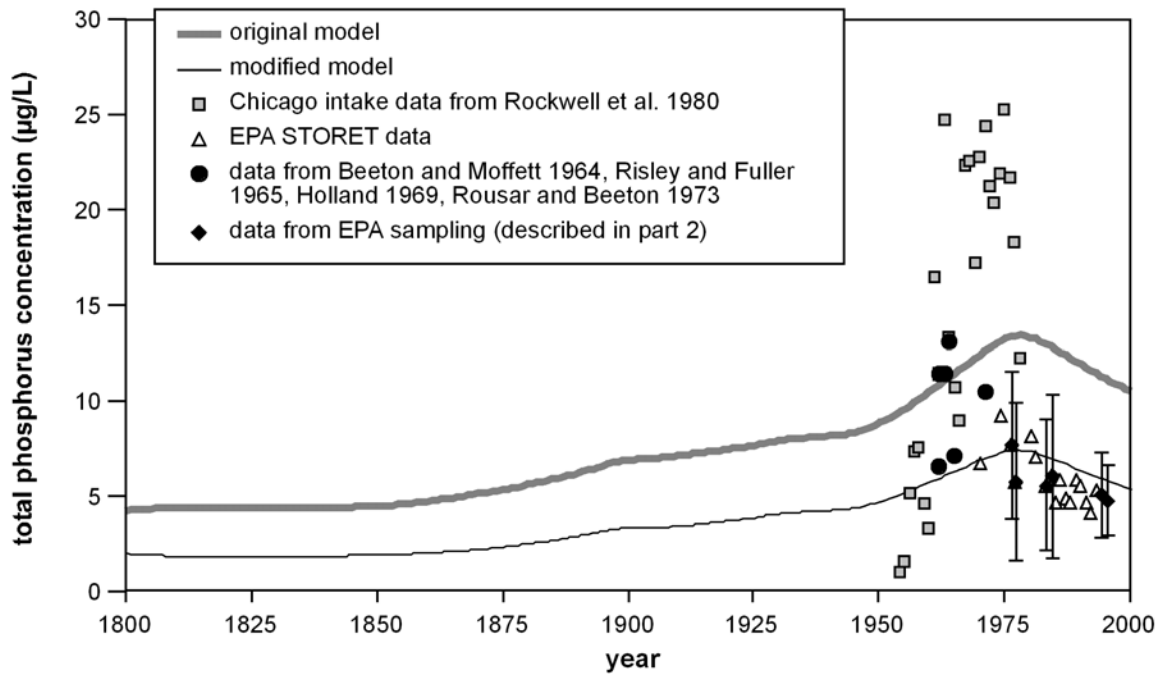
Figure 4.5.5.2. Model output versus measured total phosphorus concentration data. Error bars are ± 1 standard deviation.
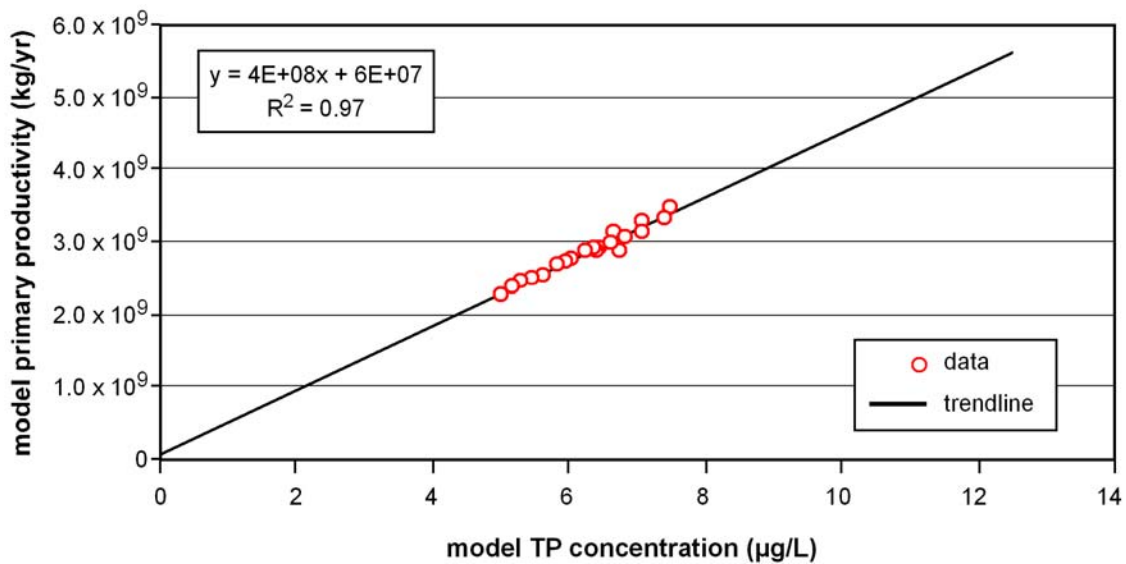

Figure 4.5.5.3. Relationship between lake-wide total phosphorus concentration and primary productivity based on model output from the LM3-Eutro model.

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